

# OSSE observations of 1E 1740.7–2942 in 1992 September

G.V. Jung<sup>1,2</sup>, J.D. Kurfess<sup>2</sup>, W.N. Johnson<sup>2</sup>, R.L. Kinzer<sup>2</sup>, J.E. Grove<sup>2</sup>, M.S. Strickman<sup>2</sup>,  
W.R. Purcell<sup>3</sup>, D.A. Grabelsky<sup>3</sup>, and M.P. Ulmer<sup>3</sup>

<sup>1</sup> Universities Space Research Association, 300 D Street SW, Suite 801, Washington DC 20024

<sup>2</sup> Naval Research Laboratory, Code 7650, Washington DC 20375-5352

<sup>3</sup> Dept. of Physics and Astronomy, Northwestern University, Evanston, IL 60208

Received July 6, 1994; accepted Jan 5, 1995

**Abstract.** We present data on the galactic X-ray source 1E 1740.7–2942 from the Oriented Scintillation Spectrometer Experiment (OSSE) on board NASA’s Compton Gamma Ray Observatory. Episodes of increased low-energy gamma radiation have been reported from this source, including 1-day events in 1990 October and 1992 September. These events, of intensity  $7 \times 10^{-3}$  and  $4 \times 10^{-3}$  photons  $\text{cm}^{-2} \text{s}^{-1}$ , respectively, have been interpreted as broadened and redshifted positron annihilation radiation. OSSE conducted observations of the Galactic Center region during a 21-day interval from 1992 September 17 thru 1992 October 8. This includes the time of increased 200–450 keV emission from 1E 1740.7–2942 reported by SIGMA. The OSSE observations do not confirm this event. For the specific outburst recorded by SIGMA, 1992 Sep. 19.42–20.58 (UT), OSSE data provide an upper limit ( $3\sigma$ ) of  $2.4 \times 10^{-3}$  photons  $\text{cm}^{-2} \text{s}^{-1}$ .

**Key words:** Galaxy: center of – Gamma-rays: observations – Stars: individual: 1E 1740.7–2942

## 1. Introduction

Extensive observations of low-energy gamma radiation from the Galactic Center region have been undertaken for over twenty years. A prominent feature in the spectrum is a narrow 0.511 MeV line due to positron annihilation and an associated continuum below this energy from the 3- $\gamma$  annihilation of positronium (see Purcell et al. 1993; Harris et al. 1990; references therein). Observations of the Galactic Center in the late 1970’s and early 1980’s provided some evidence for variability in the narrow 0.511 MeV component (Riegler et al. 1985; Paciesas et al. 1982; Leventhal et al. 1989), generating considerable interest in one or more discrete sources of positrons near the Galactic Center. The variable nature of the narrow 0.511 MeV

emission has been challenged by observations of SMM (Share et al. 1990), by the early results of the OSSE instrument (Purcell et al. 1993), and by a re-analysis of the *HEAO-3* data (Mahoney, Ling, and Wheaton 1994).

Three transient events associated with the X-ray source 1E 1740.7–2942 (hereafter, “1E 1740”),  $\sim 1^\circ$  from the Galactic Center, have been reported by the imaging gamma-ray telescope SIGMA on board the GRANAT spacecraft (Sunyaev et al. 1991; Bouchet et al. 1991; Churazov et al. 1993; Cordier et al. 1993). These transients from 1E 1740 were characterised as broad-line excesses in the 0.3–0.6 MeV range; they have been interpreted as arising from positron annihilation near a galactic black hole.

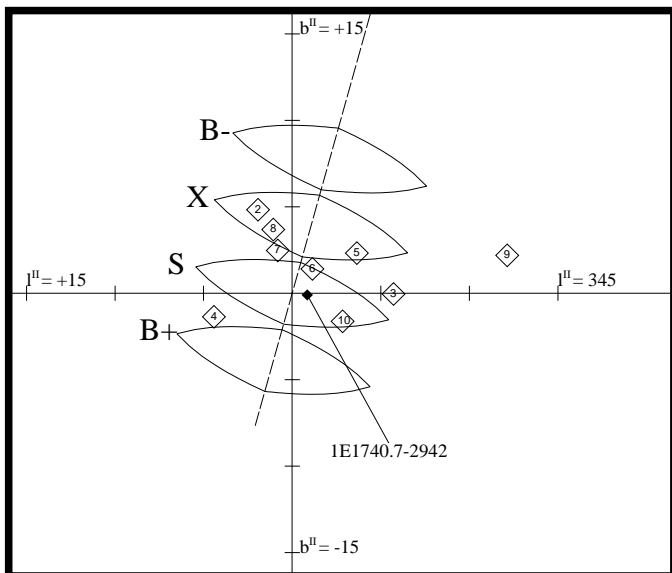
A relation of the broad-line transients to the putative variable component of the narrow 0.511 MeV line has been proposed (Ramaty et al. 1992; Durouchoux et al. 1994). In this model, positrons escape from a pair-dominated plasma near the black hole to the surrounding accretion disk; there they produce the thermally broadened and gravitationally redshifted annihilation radiation as observed in the three SIGMA observations. A portion of the positrons escape the accretion environment, possibly ejected in the recently discovered radio jet (Mirabel et al. 1991), and annihilate in a surrounding molecular cloud (Bally and Leventhal 1991) to produce a long-term variable component in the narrow 0.511 MeV emission.

The Oriented Scintillation Spectrometer Experiment (OSSE) on board NASA’s Compton Gamma Ray Observatory (CGRO) has a substantially improved sensitivity relative to previous instruments, so that outbursts as previously reported would appear in OSSE data at a very high significance. Extensive observations of the Galactic Center region have been made by OSSE since July, 1991; when possible, these were coordinated with the SIGMA schedule. The overlapping SIGMA/OSSE observations include the SIGMA detection of 1992 Sep. 19.4–20.6, indicating a broad emission feature from 1E 1740 (Cordier et al. 1993). This period is the fourth day of a 21-day OSSE observation of the Galactic Center region. The transient was charac-

terised in the SIGMA data as a broad gaussian at 350 keV with a flux  $4.3^{+2.7}_{-1.5} \times 10^{-3}$  photons  $\text{cm}^{-2} \text{s}^{-1}$  (Cordier et al. 1993). A transient with intensity in the 68% confidence range of the SIGMA report would have been detected in the OSSE data as an excess, on that day, at the  $5 - 13\sigma$  level. No such excess is found in the OSSE data.

## 2. Observations

The OSSE instrument consists of four identical large-area NaI(Tl)–CsI(Na) phoswich detectors operating between 0.05 and 10 MeV. Each detector has an effective area of 500  $\text{cm}^2$  at 0.511 MeV, and is shielded by active and passive elements which define a rectangular field-of-view of dimensions  $3.8^\circ \times 11.4^\circ$  (FWHM) at 500 keV. The detectors are independently oriented relative to the spacecraft about a common axis. Observations of cosmic sources are made along the scan path, perpendicular to this axis. A detailed description of the OSSE instrument and analysis techniques are given in Johnson et al. (1993).



**Fig. 1.** Orientations of the OSSE detectors during the 1992 September observations. The 50% response contour of the OSSE instrument for the source fields (marked **S** and **X**) and for the two background fields (**B**– and **B**+) are shown in galactic coordinates with the positions of selected X-ray sources: 1) 1E1740.7–2942; 2) GX 1+4; 3) GX 354+0; 4) GRS 1758–258; 5) Terzan 2; 6) GRS 1734–292; 7) SLX 1735–269; 8) KS 1731–260; 9) 4U1700–37; 10) 1H 1743–32.2

The fields of view used in the 1992 September observation of the Galactic Center region are shown, in galactic coordinates, in Fig. 1. Positions of selected hard X-ray sources are identified by numbered diamonds in the map. The dashed line through the center of the map is the scan

path of the OSSE detectors. The source fields (marked **S** and **X**) and the two background fields (marked **B**– and **B**+) are shown by 50% response contours of the OSSE collimator. When the earth did not occult the Galactic Center region, a detector dwelt on one of the four positions, for two minute intervals, in the sequence:

**B**–, **S**, **B**+, **X**, **B**–, **S**, ...

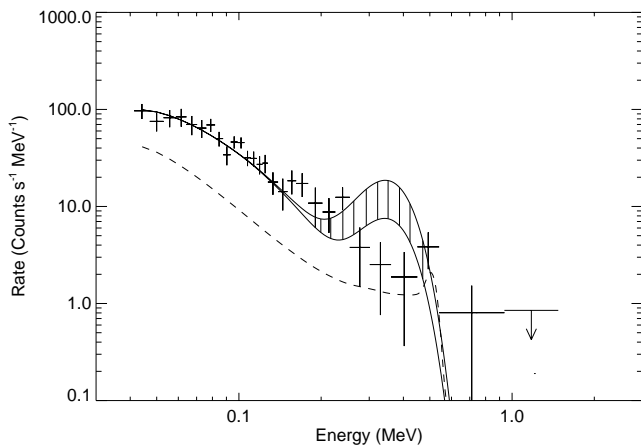
The detector background was estimated for each **S** period by quadratic interpolation, in time, of three or four of the **B**– and **B**– observations. The subtracted spectra were then averaged into day-long sums for display.

## 3. Results

The background-subtracted spectrum of the **S** field (Fig. 1) for the period 1992 Sep. 19.4–20.6 is plotted in Fig. 2. In addition to the source 1E 1740, the OSSE spectrum includes contributions from galactic diffuse emission and from other compact sources in the field-of-view. An estimate of these contributions, based on previous OSSE observations, is shown by the dashed curve. The observation reported in Cordier et al. (1993) is represented in the figure with a plot of their fitted spectral model for 1E 1740 on this day, as it would appear in OSSE data. The SIGMA model is shown with a solid line that separates to a hatched region indicating the ( $\pm 1\sigma$ ) error of the broad-line transient reported in Cordier et al. (1993). This reported feature is clearly in excess of the measured OSSE spectrum on that day. Above 200 keV and below 450 keV the OSSE spectrum is dominated by the continuum component of galactic positron annihilation radiation.

Light curves of the OSSE observation for the **S** field are shown in Fig. 3. These are daily averages of the background corrected spectra, summed in the energy bands 40–80 keV, 80–180 keV, and 200–450 keV. All count-rate units given refer to the rate of a single OSSE detector. For reference, OSSE observations of the Crab Nebula produce a rate of  $\approx 20$  counts/sec, per detector, in each of the two lower-energy bands. The SIGMA observation periods are marked with hatched boxes in the lower light curve. From these light curves it is evident that there are no significant spectral changes in the 1E 1740 emission throughout the 21-day observation period.

The OSSE data do not show a significant increase in emission from 1E 1740 (or other sources in the field of view) at any time in the 200–450 keV range. This is the band in which transient emission from 1E 1740 was observed in the SIGMA map of 1992 Sep. 19–20 (Cordier et al. 1993). The effect of the transient reported by SIGMA would be an excess in OSSE of 1–3 counts/sec above the average level, corresponding to the 68% confidence range of the SIGMA report. This range is shown with a thick error bar on the 200–450 keV light curve (Fig. 3). From the 200–450 keV light curve we obtain an upper limit ( $3\sigma$ ) of



**Fig. 2.** OSSE difference spectrum for the period 1992 Sep. 19.4–20.6 for the field **S** of Fig. 1, relative to the backgrounds **B+** and **B-**. An estimate of the galactic background emissions in the OSSE spectrum is indicated by the dashed curve. The observations reported in Cordier et al. (1993) are represented by their fitted spectral model for 1E 1740 on this day, as it would appear in the OSSE detector data. This is shown with a solid line and a hatched region indicating  $\pm 1\sigma$  error of the gaussian intensity reported for the model of the observed SIGMA transient.

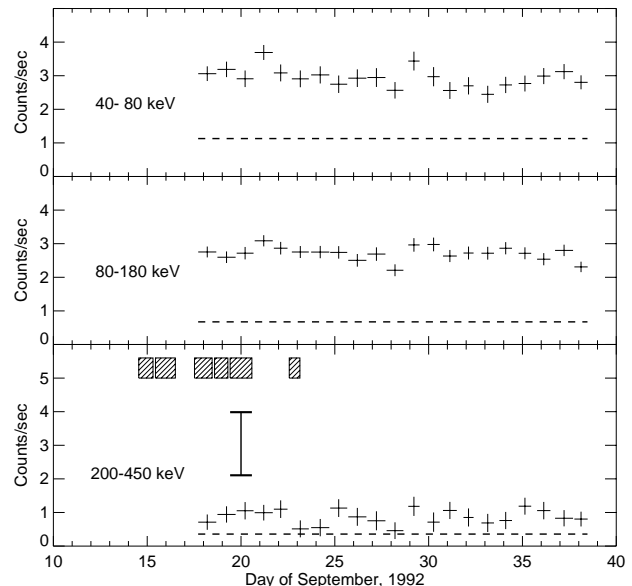
$2.4 \times 10^{-3}$  photons  $\text{cm}^{-2} \text{s}^{-1}$  for the broad-line transient as reported by SIGMA.

To further quantify the level at which we may assert that no broad-line transient appeared from the source, we fitted the spectral data of the one day (after subtracting the mean spectrum of the other days) to gaussian shapes centered between 0.3–0.55 MeV and having widths ranging from .05 to .3 MeV FWHM. For each of these gaussian shapes we determined the dependence of the chi-squared statistic on the line intensity near the best-fit value, and from this a shape-dependent limit on the intensity of a transient gaussian. This limit (99.9%) varies from  $0.4 \times 10^{-4}$  photons  $\text{cm}^{-2} \text{s}^{-1}$  for narrow, low-energy lines to  $2.3 \times 10^{-3}$  photons  $\text{cm}^{-2} \text{s}^{-1}$  for broad, high-energy lines. For the particular set of gaussian shape parameters quoted in the model of Cordier et al. (1993) we obtain an upper limit ( $3\sigma$ ) of  $1.0 \times 10^{-3}$  photons  $\text{cm}^{-2} \text{s}^{-1}$ .

#### 4. Discussion

The OSSE observations in the fall of 1992 were continuously sensitive, over a period of 21 days, to transient emission events from 1E 1740; none were observed. The event of 1992 Sep. 20, detected by SIGMA with moderate statistical confidence (99%), is in conflict with the more sensitive OSSE data.

The Galactic Center region and 1E 1740 have been extensively monitored by the SIGMA and OSSE instruments since 1990 March. In addition to the 1992 Sep. 20 event discussed here, SIGMA has reported a more significant 1-



**Fig. 3.** OSSE count rate history during the observation, in three energy bands. Estimates of the rate due to galactic background emissions are plotted with thick dashed lines. Time intervals marking the SIGMA observations are indicated by the hatched boxes in the lower (200–450 keV) plot. In the observation of September 20, they report a high-energy transient excess (Cordier et al., 1993). The effect this would have on the OSSE 200–450 keV light curve (bounded by the SIGMA 68% confidence interval) is shown by the thick error bar.

day event from 1E 1740 on 1990 Oct. 13–14 (Sunyaev et al. 1991; Bouchet et al. 1991). A third event of enhanced 0.2–0.5 MeV emission was reported for a two week period in 1991 October (Churazov et al. 1993). The 1991 and 1992 events took place during OSSE observations of the Galactic Center. As reported here, OSSE does not confirm the SIGMA transient of 1992 Sep. 20; a report on the OSSE data relevant to the 1991 Oct. transient will be made in a subsequent publication.

Other transient emissions, plausibly associated with positron annihilation, have been reported from black-hole candidates. These include MeV excesses from Cygnus X-1 (Ling et al. 1987) and the Galactic Center region (Riegler et al. 1985), and a long-term transient, similar in spectrum to the SIGMA transients from 1E 1740, from an unidentified source south of the Galactic Center (Briggs et al. 1994). These observations are in contrast to the non-detection of such events in the nine years of SMM data. The SMM upper limit for broadband transients at MeV energies, on time scales of 12 days or longer, was ( $3\sigma$ )  $\lesssim 5 \times 10^{-3}$  photons  $\text{cm}^{-2} \text{s}^{-1}$  (Harris et al. 1993); this applies to the ‘MeV excess’-type transient from all sky directions for  $\sim 3$  months of each year, 1981–1989. The SMM data also show no evidence, from the Galactic Center direction, for broad-line transients of the kind reported by SIGMA from 1E 1740. Although the SMM data are not

concurrent with SIGMA observations, the limits are not consistent with the frequency implied by all three SIGMA detections of gaussian-like spectral features from 1E 1740 (Harris et al. 1994).

In view of the suggested connection between observable positron annihilation transients and galactic black hole candidates, continued monitoring with high sensitivity instruments takes on added importance. More compelling evidence for a transient annihilation event from 1E 1740 took place 1990 Oct. 13–14, prior to the launch of CGRO. Another observation of transient features, plausibly associated with positron annihilation, was reported by SIGMA from observations of Nova Muscae 1991 (GRS 1124–684) (Sunyaev et al., 1992; Goldwurm et al., 1992). This Nova is one of the few black hole candidates with a well-determined mass of the compact object. Confirmation of such transients would provide strong support for pair plasma models of black hole radiation, lending credence to the suggestion (e.g. Ramaty et al. 1994; Durouchoux et al. 1994) that sources such as 1E 1740 might be a significant source for the positrons which populate the central region of the galaxy.

This work is supported under NASA grant DPR S-10987C.

## References

- Bally, J., and Leventhal, M. 1991, *Nature*, 353, 234.
- Bouchet, L., Mandrou, P., Roques, J.P., et al., 1991, *ApJ*, 383, L45.
- Briggs, M.S., Gruber, D.E., Matteson, D.L., and Peterson, L.E. 1994, *Proc. Second Compton Symposium*, ed. Fichtel, Gehrels, Norris (New York: AIP 304, p. 250)
- Churazov, E., Gilfanov, M., Sunyaev, R., et al. 1993, *ApJ*, 407, 752.
- Cordier, B., Paul, J., Ballet, J., et al. 1993, *A&A*, 275, L1.
- Durouchoux, Ph., Wallyn, P., and Chapuis, C. 1994, *ApJS*, 92, 405.
- Goldwurm, A., Ballet, J., Cordier, B., et al. 1992, *ApJ*, 389, L79.
- Harris, M.J., Share, G. H., Leising, M. D., Kinzer, R. L., and Messina, D. C., 1990, *ApJ*, 362, 135.
- Harris, M.J., Share, G. H., Leising, M. D., and Grove, J. E. 1993, *ApJ*, 416, 601.
- Harris, M.J., Share, G. H., and Leising, M. D. 1994, *ApJ*, 433, 87.
- Johnson, W.N., Kinzer, R., Kurfess, J., et al. 1993, *ApJS*, 86, 693.
- Leventhal, M., MacCallum, C.J., Barthelmy, S.D., et al. 1989, *Nature*, 339, 36.
- Ling, J.C., Mahoney, W.A., Wheaton, W.A., and Jacobson, A.S. 1987, *ApJ*, 321, L117.
- Mahoney, W.A., Ling, J.C., Wheaton, W.A. 1994, *ApJS*, 92, 387.
- Mirabel, I.F., Rodriguez, L.F., Cordier, B., Paul, J., and Lebrun, F., 1991, *Nature*, 358, 215.
- Paciesas, W.S., Cline, T.L., Teegarden, B.J., et al. 1982, *ApJ* 260, L7.
- Purcell, W.R., Grabelsky, D.A., Ulmer, M.P., et al. 1993, *ApJ*, 413, L85.
- Ramaty, R., Leventhal, M., Chan, K.W., and Lingenfelter, R.E. 1992, *ApJ*, 392, L63.
- Ramaty, R., Skibo, J.G., and Lingenfelter, R.E. 1994, *ApJS*, 92, 393.
- Riegler, G.R., Ling, J.C., Mahoney, W.A., Wheaton, W.A., and Jacobson, A.S. 1985, *ApJ*, 294, L13
- Share, G., Leising, M., Messina, D., and Purcell, W. 1990, *ApJ*, 358, L45.
- Sunyaev, R., Churazov, E., Gilfanov, M., et al. 1991, *ApJ*, 383, L49.
- Sunyaev, R., Churazov, E., Gilfanov, M., et al. 1992, *ApJ*, 389, L75.